# <Division of Materials Chemistry> Magnetic Materials

# Division of Materials Chemistry
## - Magnetic Materials -

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Prof
ONO, Teruo
(D Sc)

Assoc Prof
KOBAYASHI, Kensuke
(D Sc)

Assist Prof
KASAI, Shinya
(D Sc)

Assist Prof (NEDO)
YAMAGUCHI, Akinobu
(D Sc)

Techn
KUSUDA, Toshiyuki

### Students

OOKOUCHI, Takuo (D3)
JIKO, Norihiro (D3)
HIMENO, Atsushi (D2)
TANIGAWA, Hironobu (M2)
MORIMOTO, Yasumasa (M2)
WATANABE, Shinichi (M2)
DELMO, Michael Picazo (M1)
TAMADA, Yoshinori (M1)
YANO, Kuniaki (M1)

### Visitors

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|---|---|
| Prof HILLEBRANDS, Burkard | Technische Universitaet Kaiserslautern, Germany, 11 April 2005 |
| Dr PARKIN, Stuart | IBM Almaden Research Center, USA, 14 June 2005 |
| Prof AHARONY, Amnon | Tel Aviv University, Israel, 24 October 2005 |
| Prof ENTIN-WOHLMAN, Ora | Tel Aviv University, Israel, 24 October 2005 |

## Scope of Research

The conventional electronics utilizes only the “charge” of electrons, while the traditional magnetic devices use only “spin” degree of freedom of electrons. Aiming at the complete control of both charge and spin in single solid-state devices, a new field called spintronics is rapidly developing and impacting on information technology. By combining the atomic-layer deposition with nanofabrication, we focus on the development of spin properties of various materials and the control of quantum effects in mesoscopic systems for novel spintronics devices.

## Research Activities (Year 2005)

### Presentations

Thermal Effect on Current-driven Domain Wall Motion in Magnetic Nanowires, Yamaguchi A, Nasu S, Tanigawa H, Ono T, Workshop on Thermally Assisted MRAM and Thermo-magnetics, 9 April 2005, Nagoya, Japan.

Depth-Profile of Spin Polarization in Nonmagnetic Layers of Epiaxial Fe/Au(001) Multilayers by Resonant X-ray Magnetic Scattering, Ohkochi T, Mibu K, Hosoito H, Otsuka Y, Kodama K, Kasai S, Ono T, 50th Magnetism and Magnetic Materials Conference, 30 October-3 November 2005, San Jose, California, USA.

Ratchet Effect of a Magnetic Domain Wall in Asymmetric Magnetic Wires, Himeno A, Kasai S, Ono T, 50th Magnetism and Magnetic Materials Conference, 30 October-3 November 2005, San Jose, California, USA.

Domain Wall Resistance in FePt Wire with Perpendicular Magnetic Anisotropy, Tanigawa H, Yamaguchi A, Kasai S, Ono T, Seki T, Shima T and Takanashi K, 50th Magnetism and Magnetic Materials Conference, 30 October-3 November 2005, San Jose, California, USA.

Reduction of the Threshold Current Density for the Current-driven Domain Wall Motion by Shape Control, Yamaguchi A, Tanigawa H, Yano K, Kasai S, and Ono T, 50th Magnetism and Magnetic Materials Conference, 30 October-3 November 2005, San Jose, California, USA.

Spin Structures of Chromium in Epitaxial Multilayers Cr(001)/X (X=Sn, Au, V), Jiko N, Otsuka Y, Mibu K, Takeda M, 50th Magnetism and Magnetic Materials Conference, 30 October-3 November 2005, San Jose, California, USA.

### Grants

Ono T, Control of Physical Properties by Utilizing Spin-Polarized Current, Grant-in-Aid for Scientific Research (A), 1 April 2005 - 31 March 2008.

Ono T, Invention of Anomalous Quantum Materials, Grant-in-Aid for Scientific Research in Priority Areas, 1 April 2004 - 31 March 2010.

## Synthesis of the World's Smallest Magnets

Arrays of monodisperse FePt nanocrystals in the $L1_0$ structure are excellent candidates for future recording media with ultrahigh densities beyond 1 Tb/in$^2$. We successfully synthesized monodisperse $L1_0$-FePt nanocrystals that are not only superior in magnetism but also easy to handle through being dispersible in solvents. Although the thermal treatment is necessary to form the ferromagnetic $L1_0$ structure, this process induces coalescence and coarsening of nanocrystals and previously made it challenging to obtain particulate $L1_0$-FePt. We have solved this problem by coating nanocrystals with thick $SiO_2$, which allows thermal treatment even at 900°C. The protecting shell was thereafter removed in a specific way that enabled us to recover the $L1_0$-FePt nanocrystals in water dispersion. The $SiO_2$-coated nanocrystals show a high coercivity up to 18.5 kOe at room temperature in spite of their core size of only 6.5 nm in diameter. Thus, the resultant nanocrystal is the smallest magnet that is stable at room temperature and one of the most promising materials for the near-future recording media. We also demonstrated that the solvent-dispersed $L1_0$-FePt nanocrystals orient their magnetic and structural axis along an external magnetic field.

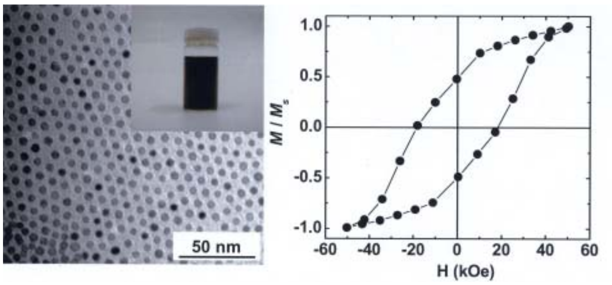


**Figure 1.** TEM image of the $L1_0$-FePt nanocrystals. Insetshows an image of the solution containing the nanocrystals (right). Room-temperature hysteresis loop in the magnetization of the nanocrystals (left).

## Ratchet Effect of the Domain Wall in Asymmetric Magnetic Wires

Magnetic domain wall (DW) motion in submicron wires can be activated not only by applying a magnetic field but also by passing an electric current through the wire. Our discovery of the current-driven DW motion has opened up very interesting perspectives for using manipulated DWs in magnetic memory and logic devices. We have extended our research to the current-driven DW motion in magnetic wires with asymmetric notches. It was found that the critical current density necessary for the current-driven DW motion depends on the propagation direction of the DW, and that the DW moves more easily in the direction along which the slope of the asymmetric notch is less inclined. In other words, the asymmetric notch works as an asymmetric potential for the current-driven DW motion (see the top panel of Fig. 2). This phenomenon may be called as a "*magnetic ratchet effect*". The middle panel of Fig.2 shows the relation between the critical current density and the applied magnetic field. Red and blue dots show the current density for the rightward and the leftward propagation, respectively. The inclinations of the two lines of the magnetic field dependence of the current density are different between the propagation directions of the DW (see the bottom panel of Fig.2), which supports the asymmetric potential due to the asymmetric notches.

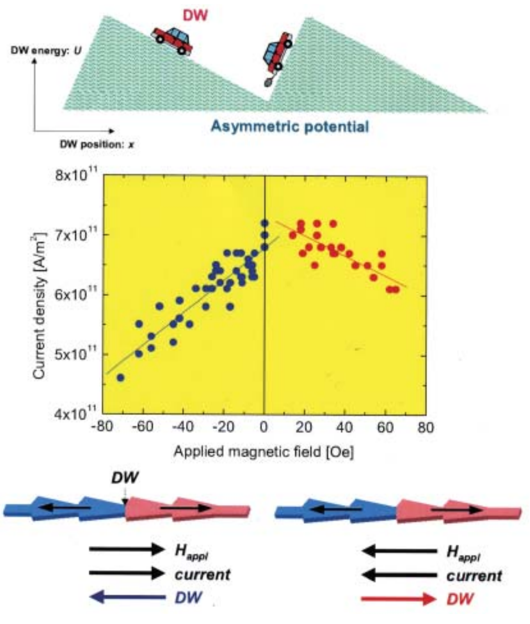


**Figure 2.** Schematic illustration of the motion of magnetic domain wall in asymmetric potential barriers (top). Magnetic field dependence the critical current density (middle). Red and blue dots show the values of the critical current density for the rightward and the leftward propagation, respectively. The magnetic stucture and the directions of a current and a magnetic field are shown (bottom).

Ono T, Development of Writing Technology for Gbit-MRAM by Using Current-driven Domain Wall Motion, Industrial Technology Research Grant Program from NEDO, 1 January 2005 - 31 December 2007.

Ono T, Magneto-transport Engineering by Spin-polarized Current, The Asahi Glass Foundation, 1 April 2005 - 31 March 2008.

### Award

Ono T, Marubun Academic Award, Marubun Research Promotion Foundation, 7 March 2005.